Numerical Calculation of Dynamics of Wiper Blade with Attack Angle

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Abstract. The automobile windshield is always made with a curvature. The oblique angle between the wiper blade and the windshield is called attack angle. Due to the attack angle, the wiper can easily jump up from the windshield while wiping, then the rainwater on the windshield is wiped off incompletely. In order to reduce this situation, it is important to clarify the dynamics of the wiper blade by taking into account the attack angle. In this study, the relationship between the attack angle and the jumping phenomenon is examined as follows. We introduce an analytical two-link model of the wiper blade that considers the exchange of dynamic and static friction between the windshield and the blade. Dynamic friction negatively related to the relative velocity of the motion, and static friction expressed by using a set-valued function that keeps the system in equilibrium. A simulation algorithm is established based on the equations of motion.

Introduction

The windshield of the automobile is generally made with a curvature to ensure excellent aerodynamic performance and aesthetics. An angle between the symmetry plane of the wiper blade and the normal vector of the windshield surface can be generated. Because the presence of the angle, which is called the attack angle, makes the wiper blade jump away from the windshield during wiping, it negatively affects the driving experience and poses a safety hazard. Therefore, it is essential to understand the dynamics of the wiper blade in consideration of the attack angle to avoid the jumping phenomenon. Lancioni et al. [1] conducted numerical analysis to elucidate how the attack angle affects the wiper blade to produce the jumping phenomenon. In addition to the slip state and stick state, the free flight state after jumping was analyzed. They found that a chattering of about 100 Hz was produced, indicating that this is a complex vibration that mixes the above three different states of motion. However, the wiper blade was only modeled with one link.

In this study, an analytical two-link model which takes into account the attack angle [2] is introduced. A numerical calculation program based on the equation of motion of this model is developed. The slip and stick states are distinguished by the difference of dynamic and static friction. Also, two states where the shoulder contacts to the head or not are considered. In the transitions between these different states, the transition times are exactly derived by the slack variable method [3]. Furthermore, in the state subject to the static friction, the Baumgarte's stabilization method [4] is employed in the numerical calculation program.

Results and discussion

This program can calculate the dynamics of the motion of wiper blade with attack angle in one round trip. Some numerical results depending on the attack angle are shown in Fig. 1. Figure 1(c) shows the changes in the angles of two links θ and ϕ with attack angles of 10 degrees. It can be confirmed that the angles becomes 0 at the same time during the wiping process, which means both links are perpendicular to the wiping surface, and at this time the calculation program stops because of the jumping phenomenon. However, as shown in Figs. 1(a) and 1(b), the jumping phenomenon does not occur where the attack angle is 0 and 5 degrees. It can be concluded that the two links of the wiper blade becoming perpendicular to the wiping surface during the wiping process is the reason of the jumping phenomenon.

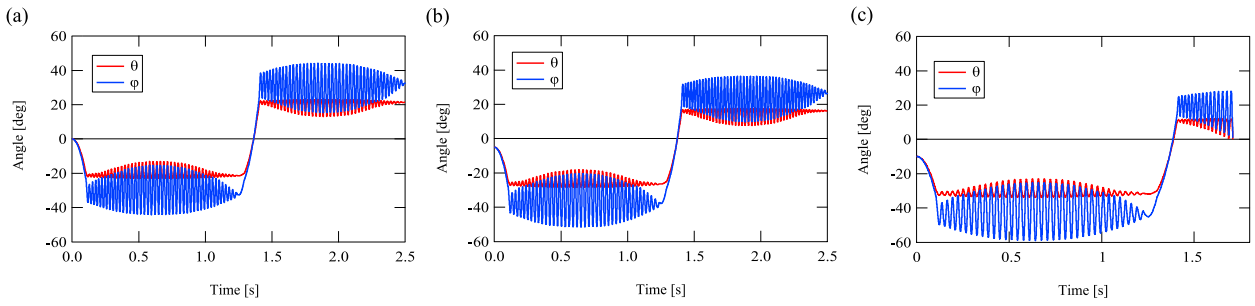

Figure 1: Numerical calculation results of the angles of the two links with different attack angles. (a) attack angle = 0°; (b) attack angle = 5°; (c) attack angle = 10°

References

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